Calibration of Highway Crash Prediction Models for other Countries - a Case Study with IHSDM

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ABSTRACT

The use of suitable crash prediction models (CPMs) is an increasing feature of rural highway design practice around the world. Given the significant undertaking required to develop these, there is a certain appeal in investigating how countries can jointly develop crash prediction models and calibrate them for each jurisdiction.

Research recently explored ways to assess the safety performance of (predominantly two-lane) rural highways in New Zealand (NZ). The Interactive Highway Safety Design Model (IHSDM) from the US was identified as worthy of further investigation, and a number of tasks were undertaken to adapt IHSDM for use in NZ.

Importing routines were developed to export NZ geometry and crash data into formats suitable for IHSDM. IHSDM's CPM was calibrated to match NZ crash patterns, both nationally and for a series of subsets defined by traffic volume, number of lanes, region and terrain. A series of validation tests were then undertaken, using actual sections of NZ highway including a "before and after" realignment case study.

These investigations showed that IHSDM is a promising tool for safety and operational assessment of highway alignments (both existing and proposed) in NZ. Incorporating crash history data generally improves IHSDM’s crash estimates, and appears to provide a better level of “local calibration” than by using sub-national calibration parameters. However, IHSDM’s current lack of consideration for bridges and inconsistent adjacent elements are notable omissions that limit the ability of the CPM to assess sub-standard existing routes with as much accuracy as well-designed newer alignments.

INTRODUCTION

The use of suitable crash prediction models (CPMs) is an increasing feature of rural highway design practice around the world. Certainly, this was part of the motivation for developing the *Interactive Highway Safety Design Model* (IHSDM) (*1*) in the US. However it would be a significant undertaking for every country to develop a similar design tool with the same degree of complexity and research. Although there are generally national differences in terms of crash rates, often there is a lot of similarity between countries in terms of crash mechanisms and contributing factors. Therefore, there is a certain appeal in investigating how countries can jointly develop crash prediction models and calibrate them for each jurisdiction.

Research has recently been completed to explore ways to assess the safety performance of (predominantly two-lane) rural highways in New Zealand (NZ) (*2*). As part of this, IHSDM was identified as worthy of further investigation for use in NZ. The main objectives of the research were:

(1) To identify road and environmental factors affecting (non-intersection) crashes on rural roads in NZ, particularly at horizontal curves.

(2) To identify the tasks required to adapt IHSDM for use in NZ and to undertake the necessary adaptations.

(3) To assess the effectiveness of IHSDM in New Zealand for predicting the relative safety of a rural road alignment, by comparing it against local highway and crash data.

A key part of the work was to calibrate and validate IHSDM for local use, particularly it's CPM. This paper outlines the investigation done to complete these tasks. The findings from this study are useful for other jurisdictions (state or national) contemplating a similar exercise.

INTERACTIVE HIGHWAY SAFETY DESIGN MODEL (IHSDM)

IHSDM is a suite of evaluation tools developed by the US Federal Highway Administration (FHWA) for assessing the safety impacts of geometric design decisions, to help planners and designers maximize the safety benefits of highway projects within the constraints of cost, environmental and other considerations. Developed since 1993, this publicly available software can help planners and designers identify and assess treatments for potential safety problems on existing or proposed highway sections (*3*).

IHSDM consists of several different analysis modules:

(1) **Crash Prediction Module (CPM)**, to estimate the number and severity of crashes on specified roadway segments.

(2) **Design Consistency Module (DCM)**, to assess the extent to which a roadway design conforms to drivers' expectations (especially speed profiles).

(3) **Driver/Vehicle Module (DVM)**, to estimate drivers' speed and path choice along a roadway.

(4) **Intersection Diagnostic Review Module (IRM)**, to evaluate intersection design alternatives, and suggest countermeasures to safety problems.

(5) **Policy Review Module (PRM)**, to verify compliance of designs with specified highway design policies and guidelines.

(6) **Traffic Analysis Module (TAM)**, to estimate the operational effects of designs under traffic flows, e.g. travel times, time spent following, vehicle interactions.

As well as a built-in highway editor, IHSDM also has import tools for major CAD/design software packages.

The initial development effort (publicly released in 2003) focused on two-lane rural highways; more recent work has started to cater for multi-lane and urban arterials as well. IHSDM has been designed to allow for local customization to suit various jurisdictions. This makes IHSDM also potentially applicable to NZ's rural State Highway network.

The CPM is of most direct interest in this paper. IHSDM's CPM algorithm consists of base models and "accident modification factors" (AMFs) for both roadway segments and at-grade intersections (*4*). The base models provide an estimate of the safety performance of a roadway/intersection for a set of assumed nominal conditions, while the AMFs adjust these predictions to account for the effects on safety of various site features, e.g. lane/shoulder width, shoulder type, horizontal curves, grades, driveway density, passing lanes, and roadside hazards.

Thus, the CPM algorithm can be used to estimate the relative safety of existing or proposed roadways. The system can be calibrated to adapt the predicted results to the safety conditions for a particular highway jurisdiction, and actual site crash history data can also be incorporated via an Empirical Bayes method.

The general outline of IHSDM's base models and AMFs also form the basis of the forthcoming *Highway Safety Manual* (HSM) (*5*), scheduled for release in early 2010, which intends to provide practitioners with crash analysis and prediction guidance over a wide variety of road and intersection types.

One factor that does not appear to be well catered for in the existing CPM is the effect of speed consistency. All of the factors used in the base model and AMFs are ascertained for each road element down the highway; there appears to be no allowance for interaction between adjacent elements. Various studies for example have demonstrated the effect on curve crash rates of the difference between approach and curve speeds (*6*,*7*).

In practice, this may not be an issue when using IHSDM to evaluate new alignments. The DCM can be used first to ensure that a reasonably consistent alignment is provided before using the CPM to estimate the likely crash rate. However, if IHSDM is also used as a tool to assess existing road alignments, then the CPM might not accurately reflect the observed crash rate. This has implications if IHSDM is being calibrated for local conditions using crash data from sub-standard or inconsistent alignments.

APPLICATION OF IHSDM TO NEW ZEALAND

Because of the wide variety of design practices and roading environments within the US, IHSDM was deliberately designed to allow for local customization, e.g. by state. Already other countries (e.g. Canada, Spain) have recognized the ability to also customize it for their own jurisdictions (*8*, *9*). Therefore, IHSDM appears to be a suitable tool for using in safety analysis in New Zealand, rather than developing a totally new road safety model.

Following initial review of IHSDM, a number of tasks have been identified to make IHSDM suitable for use in NZ, including:

- Calibrating the Crash Prediction Module with NZ crash patterns
- Developing a NZ Design Policy file based on local agency standards and guidelines
- Developing an importing routine for NZ highway geometry and crash data

The complexity and detail within IHSDM means however that such customization requires considerable effort. More detailed discussion about the CPM calibration and importing routine is given below. The development of a NZ design policy file was largely undertaken as part of a separate research project (*10*).

IHSDM was released for general public use in Sep 2004. Updated versions were released in May 2007 and Mar 2008 and these have been used for the main part of this research. The differences between these versions are largely cosmetic in nature; the underlying models for crash prediction, speed estimation, etc were not changed. A more recent version (June 2009) has now updated the CPM to align with the models in the HSM and allowed the ability to better customize the form of these models.

Existing highway and crash data plays a major role in developing the necessary inputs to IHSDM and its calibration. NZ is very fortunate in having road geometry data (horizontal curvature, gradient, crossfall) on all State Highways at 10-m intervals, as well as other detailed data on crashes, traffic volumes, cross-section, etc. Koorey (*11*) explains in more detail the process used to process this data and generate suitable road elements for this study.

CALIBRATION OF CRASH PREDICTION MODULE

A calibration procedure is provided for adapting the predicted CPM results to the safety conditions encountered by any particular highway agency. This process allows for adjustment of three factors:

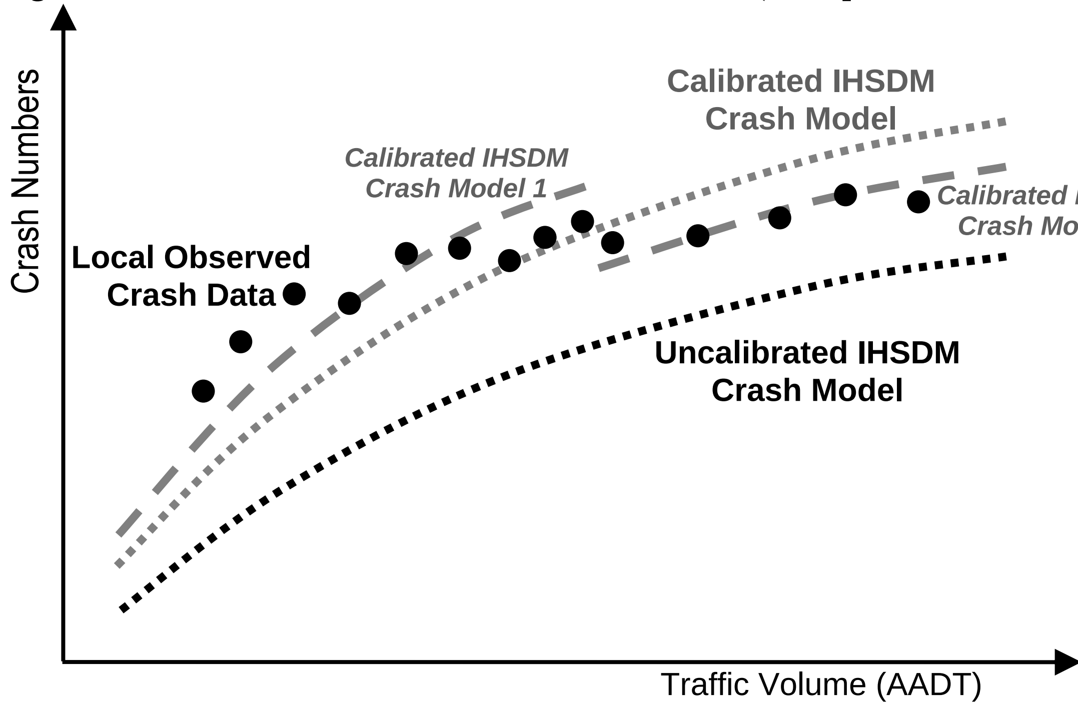
- An overall “calibration factor”, a scaling factor to adjust the overall crash numbers
- Modification of the relative proportions of crashes by injury severity
- Modification of the relative proportions of crashes by crash type

IHSDM provides spreadsheet templates to assist with the derivation of suitable calibration factors for any given jurisdiction. The spreadsheet compares the default predicted number of crashes with the actual recorded crashes, adjusted for the relative traffic volumes and total mileages on roads with different geometries (gradient, curvature, lane width, etc). Two levels of data detail (and, in theory, precision) are provided for; “Level 1” and “Level 2”, depending on what data are available in a jurisdiction (e.g. stratification by geometry, AADT, terrain and road widths).

Until the latest version of IHSDM, the form of the crash prediction models couldn’t be adjusted, except by means of scaling the overall predicted crash numbers and crash severity/type proportions. This could be problematic if crash incidence in another jurisdiction varies differently in relation to the key inputs. For example, consider the hypothetical example illustrated in Figure 1, where local observed crash data (black dots) are compared with the uncalibrated IHSDM prediction model (black dotted curve). Clearly the IHSDM model in this example under-predicts the expected number of crashes, so a calibration factor is used to scale up the prediction model to better fit the observed data (grey dotted curve). However, when plotted against the traffic volume at each site, it is apparent that even the calibrated IHSDM model is not a good fit to the observed data; at low volumes the model under-predicts the expected number of crashes, while at high volumes it over-predicts.

Without the ability to adjust the "shape" of the prediction model (e.g. the exponent applied to the traffic volume input), the only way to produce a more accurate crash estimate with IHSDM is to determine separate calibration factors for different traffic volume categories. Figure 1 shows an example of this (Crash Models 1 and 2, grey dashed curves); the differences between the observed and predicted crash numbers are much smaller now. Similarly, different calibration factors might be required for roads with (say) different types of terrain or in different regions of a jurisdiction.

Figure 1 Calibration of IHSDM to Local Crash Data (Multiple Calibration Factors)



Pragmatically speaking, the problem then becomes one of how far to disaggregate the road network and create separate calibration factors for each subset. While this may improve the accuracy of the predicted outputs, it comes at the cost of model simplicity. IHSDM users would have to select a different set of calibration parameters depending on where their project is, and a larger set of factors would need to be regularly updated as crash patterns change.

Crash Prediction Model Calibration Factors

NZ's State Highway network comprises approximately 10 400 km of (mostly rural) arterial routes; this was reduced to about 8850 km of segments for analysis, following various processing steps to correct biases and eliminate problematic sections (e.g. urban areas, recent realignments). The various road types and crash data on this network were then summarized to produce the IHSDM input values for CPM local calibration. All of the IHSDM calibration inputs are specified in US customary units (miles, feet); therefore conversion routines were required to scale the NZ data given in km and meters.

IHSDM calibration spreadsheets were used to determine scaling factors to adjust the overall crash numbers for different analysis periods (it should be noted that only road sections unchanged during all periods were used for the calibration process). Both "Level 1 and "Level 2" calibrations were undertaken to see how much difference this made. Table 1 summarizes the calibration factors determined for NZ use overall; each calibration factor is the ratio of the observed crash numbers in NZ to the predicted crash numbers from IHSDM's calibration spreadsheet. More details about the derivation of all calibration factors in this paper can be found in (*2*).

Table 1 IHSDM Calibration Factors for New Zealand Use - Highway Segments

Crash Analysis Period	**1996-2000**	**2002-2006**
Number of Observed Crashes	18 052	20 805
Predicted No. of Crashes (IHSDM Level 1)	20 423.9	24 433.4
Level 1 Calibration Factor	**0.884**	**0.851**
Predicted No. of Crashes (IHSDM Level 2)	20 508.3	24 536.6
Level 2 Calibration Factor	**0.880**	**0.848**

The results suggest that the crash numbers in NZ are lower than those observed in the US; this could reflect a slightly better road safety record in NZ or a better reporting rate in the US (unlike NZ, most US jurisdictions have a minimum property damage value for which it is mandatory to report a crash).

It is interesting to note that the calibration factors above do not vary much between Level 1 and Level 2. This suggests that the much simpler Level 1 data requirements may be sufficient for a reasonably accurate crash prediction in NZ.

Disaggregation of Model Calibration Factors

To test the relative accuracy of the base calibration factors when working with a smaller part of the network, the (1996-2000) crash and network data were subdivided into various categories and new calibration factors recalculated for each subset. Table 2 shows the various resulting factors (for readability, the predicted crash numbers have not been listed).

Table 2 IHSDM Subset Calibration Factors

Subset	Number of Observed Crashes	Total Length	Level 1 Factor	Level 2 Factor
Overall (whole of NZ)	18 052	8854.63 km	0.884	0.880
2-Lane Sections	16 465	8541.66 km	0.892	0.890
3-Lane Sections	1 401	271.96 km	1.106	1.090
4-Lane Sections	134	33.18 km	0.879	0.791
AADT <1000 veh/day	1 987	3061.29 km	1.104	1.120
AADT 1000 - 3000 veh/day	4 936	3312.31 km	0.864	0.860
AADT 3000 - 5000 veh/day	4 244	1322.72 km	0.911	0.914
AADT 5000 - 10 000 veh/day	4 405	872.84 km	0.908	0.910
AADT > 10 000 veh/day	2 480	286.26 km	0.742	0.739
Flat Terrain	7 469	3666.08 km	0.843	0.839
Rolling Terrain	7 247	3731.97 km	0.921	0.918
Mountainous Terrain	3 336	1457.05 km	0.915	0.912
Northland (above ave. crash risk)	1 379	627.57 km	0.914	0.916
Waikato (average crash risk)	3 757	1455.72 km	0.791	0.789
Otago (below ave. crash risk)	1 282	1146.64 km	0.822	0.823

The network is predominantly two-lane, with relatively few lengths of three- or four-lane passing lane sections (<4%) and a small amount of single-lane sections that were ignored for this analysis. The results clearly show some differences in the respective calibration factors by number of lanes, although the considerably smaller sample sets for three/four-lane segments may have some effect on the relative variations showing here. The most anomalous factors are for three-lane sections; IHSDM applies a 25% crash reduction assuming that they are operationally warranted and their length is appropriate for the roadway's operational conditions (*4*). Based on previous work in NZ (*12*), it is suspected that some of the existing passing lane segments here do not fully meet these criteria, and thus their safety effect may be considerably less than 25%. This would result in calibration factors closer to the overall average.

No clear trend emerges in terms of changing traffic volume; this would suggest that the "shape" of IHSDM's CPM volume parameter is reasonably appropriate for NZ. Although the calibration factors for high volume (> 10 000 vpd) roads are lower than the other volume bands, over 21% of road length with such volumes have three/four lanes; allowing for these would bring the calibration factors more in line with the others. The only other category to be wary of is the "<1000 vpd" group, where possibly lower design standards are producing higher calibration factors.

Crash patterns may also vary by terrain, i.e. in terms of how vertical alignment changes. IHSDM's calibration routine seeks data on the relative proportion of road length in "flat", "hilly", and "mountainous" terrain; however nowhere are these terms described in clear quantitative terms. One measure is to use "hilliness", usually defined as the rate of rises or falls along a road. For example, a constant grade of 1% has a hilliness of 10 m per km. Based on inspection of the geometric elements database, three terrain definitions were determined, striking a reasonable balance between terrain extremes while ensuring sufficient numbers in each category. There does not appear to be any clear trend as terrain worsens, with the calibration factors all reasonably similar. Again, it is likely that there are more three/four-lane roads in flat terrain than hilly/mountainous terrain, which probably helps explain the lower calibration factors for the former.

Crash rates may also vary by region, where local topography, climate, and safety programs may have an effect. The variation in crash risk (social cost per veh-km) by NZ region was investigated (*13*). Three of the larger regional networks with a range of crash risks were chosen for more specific analysis. Again, no consistent trend is apparent; although the worst performing region (Northland) does have higher calibration factors as might be expected. The results may also be complicated by the other variations within each region; for example Waikato has the highest average traffic density whereas Northland has the greatest proportion of mountainous road terrain.

An attempt was made to undertake some statistical analysis of the above calibration factors, to determine whether there were statistically significant differences within each set of factors and in comparison with the overall calibration factors. This was not a straightforward exercise, as the distribution of the calibration factors is not likely to follow a standard distribution (e.g. Normal distribution). A variety of tests were considered, including Pearson Chi-square (χ^2) tests, Welch *t*-Tests, and Mann-Whitney *U* tests. The results generally tended to support having the same overall IHSDM calibration factor for virtually all situations. However, some caution needs to be taken when dealing with road sections with particularly low (<1000 vpd) or particularly high (>10,000 vpd) traffic volumes. The results may also not be as accurate in some regions of the country.

Two other considerations should assist the use of a common calibration factor:

- The use of local crash history data in IHSDM will help to further refine the crash estimates in the same way that a localized calibration factor might.
- Practically speaking, it is not clear whether the statistical tests (which combined crash numbers over the entire data-set) were that useful. For example, on a road section with (say) <5 crashes, a calibration factor of 0.88 versus 0.84 will not produce a large difference in the predicted number of crashes.

The disaggregated subset analysis also confirmed that there is little difference between the values derived using the Level 1 and Level 2 calibration procedures. Generally the difference was less than 0.01; the key exception being for the small sample of four-lane roads. Therefore, for simplification, only Level 1 calibration factors were used for subsequent analysis.

Modification of the relative Crash Severity and Crash Type Proportions

An analysis of NZ State Highway crash data was undertaken to determine suitable proportions of crashes by injury severity and crash type. This was made somewhat difficult by different definitions in each country for both severities and crash types. However, this is only an issue for comparison purposes; for use in IHSDM, it is only important that the user knows what the reported categories refer to in terms of assigned NZ severities and crash types.

One notable observation of the existing IHSDM crash prediction process is that the same crash severity and crash type proportions are applied to all road section estimates of crash numbers. This seems somewhat unrealistic, as the average severity is likely to be affected by the crash type and surrounding environment, e.g. more fatal crashes with head-on collisions or non-frangible trees. Similarly, the relative proportions of crash types are likely to vary at least with regards to traffic volumes, the number of lanes, and the curvature of the road. It would be desirable to determine relationships in IHSDM where the respective crash severities/types are affected by some of these factors.

As a result, little attention was paid to the respective proportions of crashes estimated in each category; instead the focus was the overall numbers of property-damage-only (non-injury) and fatal-and-injury crashes.

IMPORTING NZ ROAD ALIGNMENT DATA

IHSDM allows two main ways for road data to be created:

(1) Alignment data can be manually entered using IHSDM's Highway Editor tool, although this can be very time consuming, given the amount of design detail required.

(2) Industry standard LandXML files can be imported. Most roading design software packages can produce LandXML files directly from their alignment data for use within IHSDM.

Typically the data required by IHSDM comprise geometric elements (e.g. horizontal curves/tangents, vertical curves/grades, cross-section features), together with general road environment data (e.g. design speeds, terrain, traffic volumes). For proposed new alignments, obtaining these data is usually relatively straightforward as most of the necessary information will already be determined in some road design program. Assessing existing alignments requires further work to produce the necessary data, especially on a large scale.

A promising approach is to use road geometry data available for the network. Database routines can be developed to "walk" down a given highway dataset and identify the approximate start and end of each geometric element (e.g. based on horizontal curvature). Then summary information about the road geometry within the extents of each element can be produced, and a record added to a table of elements (*11*).

Using the road geometry elements produced for this study, conversion procedures were developed to create LandXML files for use in IHSDM. A test highway was first created in IHSDM, containing a variety of different geometric and traffic elements, and exported to a LandXML file to provide a template for creating other files. Database code was then developed to produce equivalent LandXML files for any selected section(s) of State Highway road and crash data.

Due to the data available, not every design aspect available in IHSDM could be coded in the import files. In some cases, necessary data was assumed to apply throughout the length of the road section for simplification e.g. roadside hazard rating, and driveway density.

VALIDATION OF IHSDM WITH LOCAL DATA

To validate the accuracy of IHSDM for New Zealand conditions, a series of tests with local sites and data were identified and developed. These included:

- Tests of the Design Consistency, Policy Review and Crash Prediction Modules on a single-lane bridge replacement and realignment
- A "before and after" crash comparison of a major highway realignment using the CPM and DCM
- Checks using the CPM of actual versus predicted crash numbers along longer lengths of highway in varying terrain

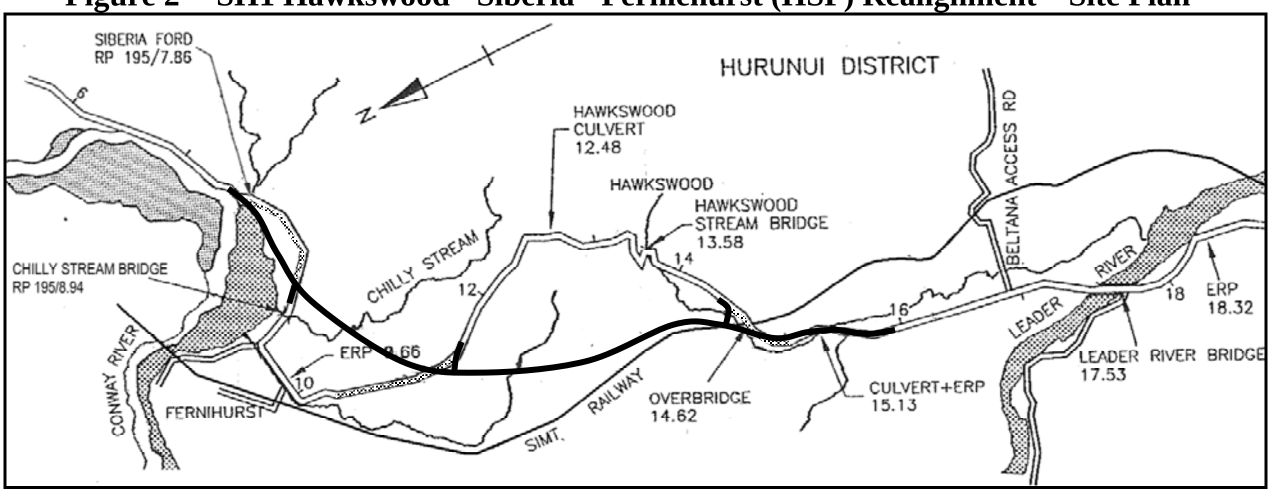
The discussions below briefly describe some of these tests; more details can be found elsewhere (*2*).

SH1 Hawkswood-Siberia-Ferniehurst Realignments

To validate the crash prediction abilities of IHSDM, an older realignment site was selected for studying. The site consists of two adjacent projects constructed at approximately the same time (1999-2001), the Hawkswood Deviation and the Siberia to Ferniehurst Realignment (collectively referred to as the "SH1 HSF Realignment" for short). They are located in the upper central part of NZ's South Island on State Highway 1. The AADT at this site was approximately 2100 vpd during construction in 2000.

Figure 2 shows the overall site plan. The new alignment is indicated by the solid black line; sections of the old alignment that have been removed are indicated by hatched lines. Parts of the old highway have been retained for local property access, with three new intersections constructed. As well as providing a more consistent design, the new 7 km alignment reduces the travel distance by approximately 2 km.

Figure 2 SH1 Hawkswood - Siberia - Ferniehurst (HSF) Realignment – Site Plan



The old alignment was a particularly winding and sub-standard section of highway, especially in comparison with the high-speed alignment immediately south of it. This included a number of narrow and poorly aligned bridges over streams and railways. Throughout the alignment, there were many curves with radii <100 m and some as low as 20 m. The new alignment takes a more direct route, involving substantial earthworks to achieve this. Horizontal radii now range between 400 m and 800 m, with a new overbridge crossing the main railway line.

The crash statistics in the "before" period (1994-98) were dominated by "lost-control cornering" and "head-on" crashes (16 injury and 17 non-injury crashes overall). During the "after" period (2002-06) the new alignment experienced only 5 injury and 7 non-injury crashes. Also, despite creating three new side-road intersections, no crashes have been reported at these locations. When compared against changes in crash numbers and traffic volumes nationally and regionally over the same period of time, the crash reductions observed at the HSF Realignment are statistically significant ($p < 0.01$).

Imported road alignment data was used in IHSDM's CPM to estimate crash numbers on the old and new alignments. The crash history data before and after the HSF Realignment works were also imported into IHSDM for processing. A Level 1 calibration factor of 0.966 for all NZ State Highway crashes over 1994-98 was used for the "before" analysis, based on the 1996-2000 factor of 0.884 (from Table 1) adjusted to reflect the relative difference in crash numbers between the two periods.

The IHSDM CPM analysis was undertaken both with and without local crash history being incorporated. In normal practice, historical crash data is used to predict the likely crash numbers of a future time period. This presents a slight problem if trying to check the accuracy of the prediction model during the "before" period (in this case 1994-98) with data from the same period. Therefore, three possible options were tested

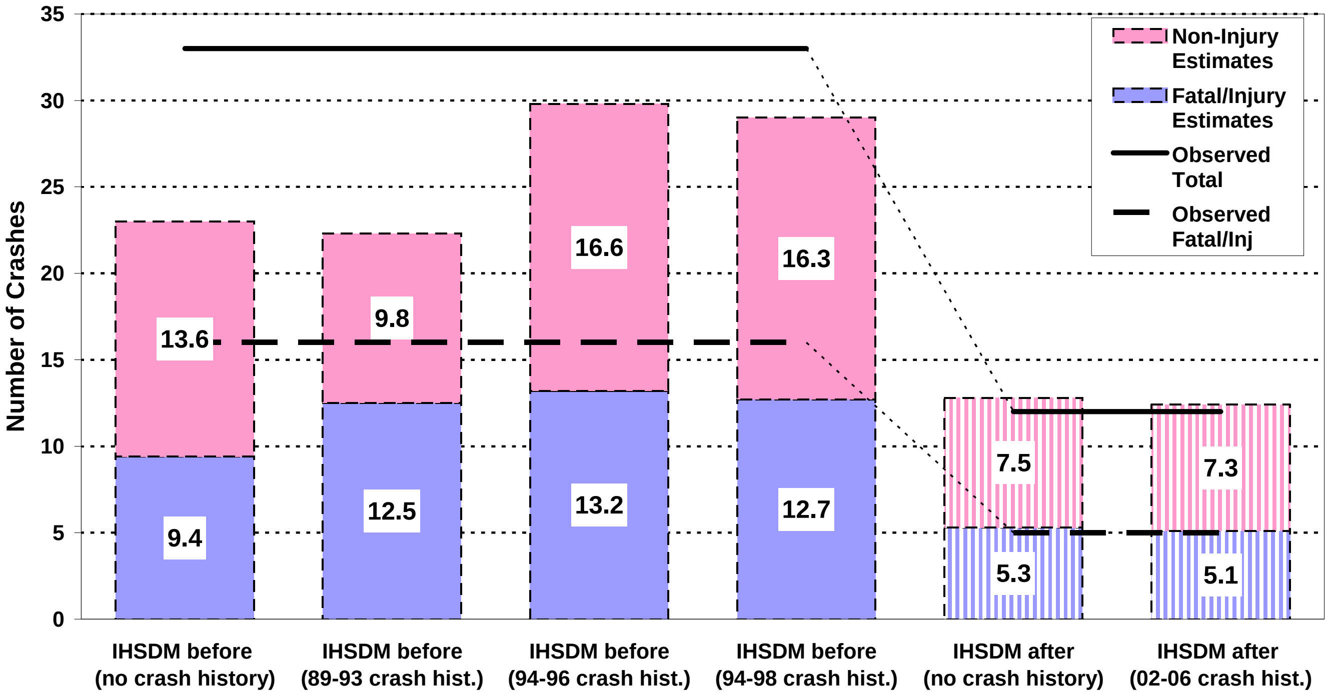
- Historical crash data from prior to the "before" period (i.e. 1989-93) was used to estimate the number of crashes. However, there was less emphasis on collecting non-injury crash data back then.
- Crash history from the first part (1994-96) of the "before" period was used.
- Crash history from the entire 1994-98 period was used.

A similar crash prediction analysis was undertaken for the "after" period, using the calibration factor derived for this period (scaling factor of 0.851, from Table 1). The earlier crash history from the "before" period would not be suitable in this case because the alignment was substantially changed. Therefore, crash history data from 2002-06 was used when testing this option. Figure 3 summarizes the various "before" and "after" crash prediction estimates by IHSDM in comparison with the observed crash numbers.

Evidently the base crash prediction model is relatively conservative when it comes to sub-standard alignments like that in the "before" case; without crash history data the CPM underestimates the actual number of crashes by about 30%. This may also reflect why the site was chosen for realignment, if it had experienced a higher-than-expected number of crashes. Alternatively, the under-estimation could be the result of not accounting for the relative inconsistencies between adjacent elements. As might be anticipated, the addition of crash history data pushed the prediction estimate much closer to the observed total number (approximately 10% under at best).

With the new alignment, the CPM gave a particularly good estimate of the actual observed numbers, even without considering crash history. The fact that this alignment has been properly designed and safety audited, rather than having just "evolved" over time like the old alignment, may explain why the CPM can more accurately estimate the number of crashes.

Figure 3 “Before” and “After” Crash Numbers on SH1 HSF Realignment



It is of interest to see whether IHSDM is basing its assessment on the same sub-standard road elements where the crashes are occurring. A comparison was made between observed and predicted crash rates along the old HSF alignment for each geometric element, including major bridges and curves. Without historical data, IHSDM show a fairly consistent crash rate throughout the alignment, with slight peaks at the major curves. However, they do not correlate particularly well with the observed crash history at some of the more extreme elements (e.g. bridges). The fact that IHSDM's CPM does not currently take directly into account bridge features seems to lead to underestimation of the safety issues at these locations. Using crash history data improved on the predictions in locations where there had been a consistent crash trend during this period.

Validation of NZ Highway Crash Numbers

Further tests were undertaken to check predicted crash numbers for three longer road sections of varying location and terrain. The CPM was tested using different calibration factors for the whole SH network, the network in the same region as the road section, and highways with the same terrain. The effect of crash history data was also examined.

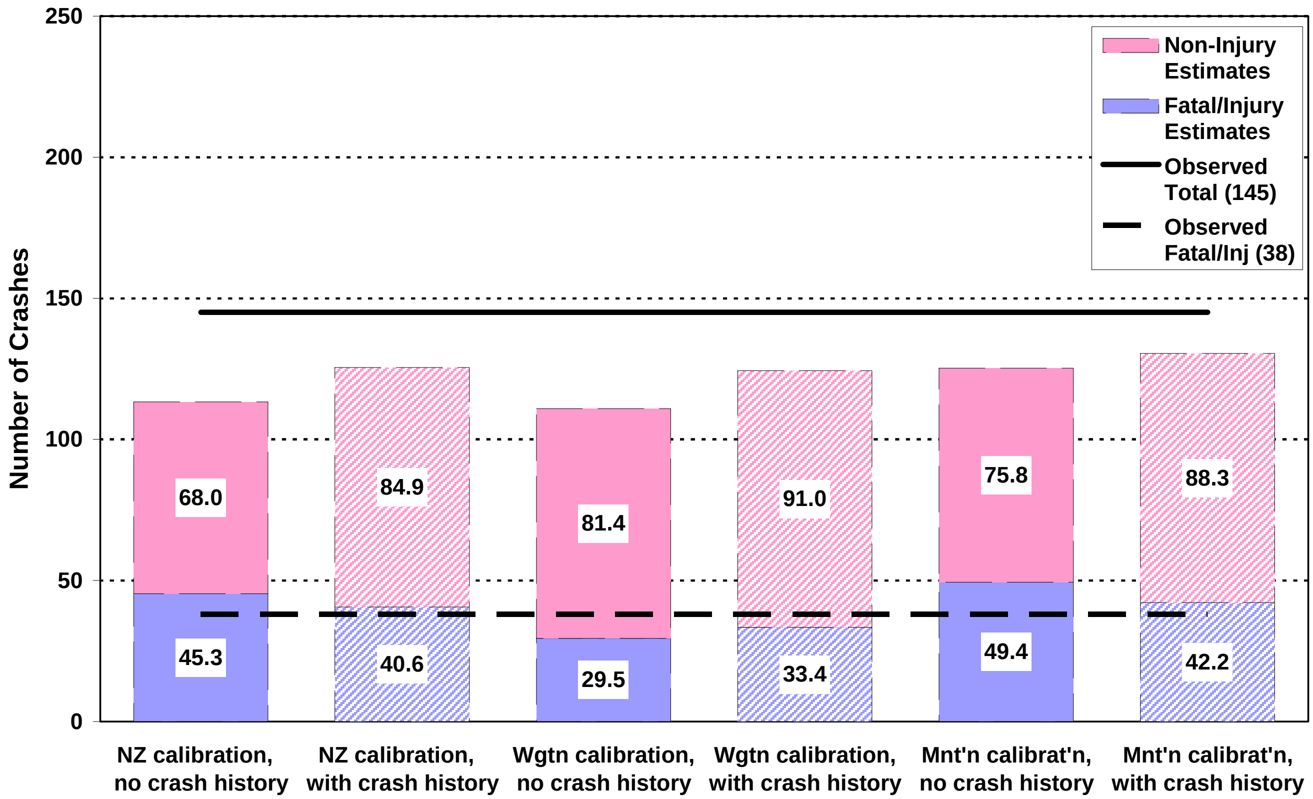
Three road sections were investigated:

- SH1S in the Canterbury region between Christchurch and Ashburton. This is ~65km of very flat terrain with typical 2001 traffic volumes of 7000-9000 vpd.
- SH1N in the Auckland/Northland region between Waipu and Wellsford. This is ~42km of rolling terrain with typical 2001 traffic volumes of 6000-7000 vpd.
- SH2 in the Wellington region over the Rimutaka Saddle. This is ~24km of mountainous terrain with typical 2001 traffic volumes of 4000-5000 vpd.

A 2000-02 crash prediction period was used (each section had between 80-150 crashes during this period), with the optional use of crash history data from 1997-99. The required road and crash data were extracted from the study database and imported into IHSDM. National, regional and terrain-based IHSDM calibration factors were then determined for the 2000-02 period.

Figure 4 summarizes the observed and estimated crash numbers for one of the sections. The estimates with and without crash history data are shown using each calibration factor (national, regional, terrain). Fatal/injury and non-injury crash numbers are separated out. For this particular site, the total crash number estimates under-predict the observed crash numbers, although some of the other sites over-predict crash numbers.

Figure 4 2000-02 Crash Numbers on SH2 Rimutaka Saddle (Wellington region)



Across all three trial sections, no clear advantage was seen by using region or terrain specific calibration factors instead of factors for NZ overall. The success of these factors depended somewhat on how representative the section under investigation is of the particular data set used for calibration.

Discussion

Although the findings varied somewhat with case study, some general trends could be identified from the validation studies:

- It is difficult for IHSDM's CPM to achieve an exceptionally good match with existing alignments (which typically have more sub-standard design elements), particularly when the input is not sufficiently detailed. However, this somewhat reflects its main purpose, which is to assess the relative merits of proposed design alignments.
- IHSDM's CPM performed much better when predicting crash numbers on sections with consistent geometric characteristics, e.g. properly designed new alignments.
- Using crash history generally improved the IHSDM estimates (or did not make them worse); this was particularly true for fatal/injury crash numbers.
- The CPM estimates for fatal/injury crashes generally were slightly more accurate than those for non-injury crashes; this probably reflects the vagaries in reporting practice still evident in NZ for the latter.

CONCLUSIONS

A number of tasks were identified to make IHSDM suitable for use in NZ. The crash prediction model was calibrated to match NZ crash patterns, both nationally and for a series of subsets defined by traffic volume, number of lanes, region and terrain. Although there were some differences in calibration parameters between the various subsets, generally they did not seem to be statistically significantly different to warrant their use instead of overall national parameters.

A series of NZ sites were tested in IHSDM to assess its crash prediction abilities and other related features such as design consistency. While appreciating that these are just a limited selection of tests, the investigations have shown that IHSDM is a promising tool for safety and operational assessment of highway alignments (both existing and proposed) in NZ.

In considering the challenge of calibrating a crash prediction model like IHSDM, the following suggestions are given:

- Crash history data is generally needed to obtain a reasonable level of precision in the CPM, particularly for sections with inconsistent or sub-standard design elements. Indeed, using crash history data appears to provide a better level of "local calibration" than attempting to derive specialized calibration parameters for each sub-region, and requires far less effort.
- For new sites being analyzed, there is of course no valid crash history data available. However, the consistent nature expected of a new alignment means that a properly calibrated IHSDM model should provide an accurate estimate of expected crash numbers.
- There appears to be little practical difference between Level 1 and Level 2 calibration; therefore, the former is recommended, given the simpler data requirements.
- Reported fatal/injury crash data provide a more consistent set to work with and to estimate crash numbers for; the vagaries of non-injury crash reporting rates can have considerable effects on the prediction process. For economic analysis purposes, this may

be sufficient anyway, given the much higher social costs associated with fatal/injury crashes compared with non-injury crashes.

- The level of detail applied to the specification of the road alignment is important for an accurate crash estimate in IHSDM, particularly for sub-standard elements. Correct specification of the extreme attributes of these elements (e.g. minimum radius, maximum roadside hazard) appears to be crucial to getting reasonably precise crash estimates at these locations.
- As seen in the SH1 HSF Realignment, the lack of consideration for bridges and inconsistent adjacent elements are notable omissions from IHSDM's CPM, and they can only be partly rectified by adjusting other attributes (such as lane/shoulder width). While this may not be much of an issue when assessing properly designed alignments, it limits the ability of IHSDM's CPM to be used with as much precision when assessing existing routes containing sub-standard elements (although the DCM highlights these elements well).
- IHSDM's crash type and crash severity estimates are of limited use in their current form, as the default values are consistently applied across all road sections. It would be desirable for some basic relationships to be included in IHSDM that adjusted the default proportions for crash type and severity to account for road environment factors such as traffic volume, design speed, horizontal curvature and roadside hazards.
- To simplify the creation of useful data segments for calibration, it is strongly recommended that roading agencies create and maintain databases of the location of key features including curves, intersections, passing lanes, and speed limits.

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